Attorney: Art Hasan
Docket No.:   42055/SAH/K415
Inventor(s):   Philip J. Kellman, Ph.D.
Title: SYSTEM AND METHOD FOR
ADAPTIVE LEARNING
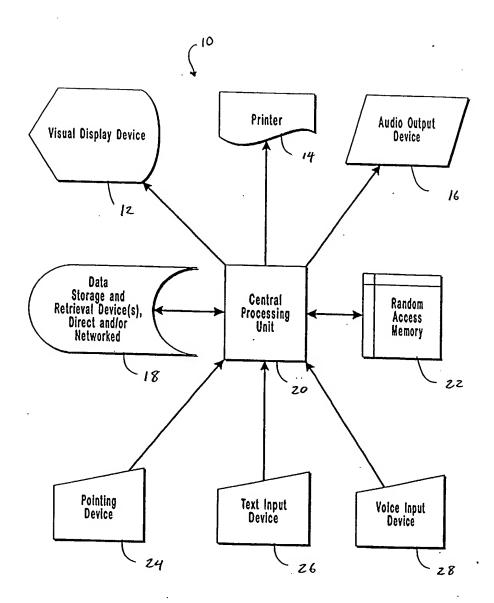   Sheet 1 of 12

10

Visual Display Device

12

Printer

14

Audio Output Device

16

Data Storage and Retrieval Device(s), Direct and/or Networked

18

Central Processing Unit

20

Random Access Memory

22

Pointing Device

24

Text Input Device

26

Voice Input Device

28

FIG. 1

FIGURE 2.   OPTIMAL SEQUENCING METHOD

TRIAL	PROBLEM	RESPONSE	RESPONSE ACCURACY	TIME (sec)	COMMENT
1	7 X 7 =	"49"	CORRECT	3.5	Fast, correct response.
2	6 X 7 =	"38"	WRONG	--	Incorrect response.
3	7 X 4 =	"28"	CORRECT	18.4	Correct but slow.
4	12 X 7 =	"72"	WRONG	--	
5	6 X 7 =	"42"	CORRECT	11.7	Recurrence of problem missed on Trial 2.
6	9 X 9 =	"72"	WRONG	--	
7	12 X 7 =	"84"	CORRECT	10.4	Recurrence of problem missed on Trial 4.
8	5 X 8 =	"40"	CORRECT	2.6	
9	9 X 9 =	"80"	WRONG	--	
10	7 X 4 =	"28"	CORRECT	6.1	Recurrence of problem answered slowly on Trial 3.
11	6 X 3 =	"18"	CORRECT	4.8	
12	9 X 9 =	"74"	WRONG	--	Recurrence of problem missed on Trial 9.
13	3 X 4 =	"12"	CORRECT	2.4	
14	6 X 7 =	"32"	WRONG	--	
15	9 X 9 =	"81"	CORRECT	4.5	Recurrence of problem answered slowly on Trial 5.
16	7 X 7 =	"49"	CORRECT	2.7	Recurrence of problem missed on Trial 12.
17	12 X 7 =	"84"	CORRECT	6.2	Recurrence of problem answered quickly on Trial 1.
18	6 X 7 =	"42"	CORRECT	5.1	Recurrence of problem answered slowly on Trial 7.
19	3 X 10 =	"30"	CORRECT	3.2	Recurrence of problem missed on Trial 14.
20	7 X 4 =	"28"	CORRECT	3.9	Recurrence of Trial 10 problem.

Table 1

Figure 1. Sample Sequence of Trials Using the Sequencing Algorithm. Relevant parameter values: a = .1, b = 2, D = 2, W = 12, K = 1. Arrows indicate selected examples of problem recurrence. (See text.)

TRIAL

PROBLEM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
7X7=	(1)	-.088	0	.088	.176	.264	.352	.44	.528	.616	.704	.792	.88	.096	1.05	(1.14)	.0078	.151	.226	.30
6X7=	1	(1)	-.12	0	(1.2)	-.148	0	.148	.296	.444	.592	.74	.888	(1.04)	-.12	0	1.2	(2.4)	.11	.22
7X4=	1	1	(1)	-.2	0	.202	.404	.606	.808	(1.01)	-.129	0	.129	.258	.387	.516	.645	.774	.903	(1.03)
12X7=	1	1	1	(1)	-.12	0	(1.2)	-.158	0	.158	.316	.474	.632	.79	.948	1.10	(1.26)	.123	.245	.368
9X9=	1	1	1	1	-.12	0	-.12	0	(1.2)	-.12	0	(1.2)	-.12	0	(1.2)	.102	.204	.307	.409	.511
5X8=	1	1	1	1	1	(1)	-.12	0	.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.85
6X3=	1	1	1	1	1	1	1	(1)	1	1	1	.106	.212	.318	.424	.530	.636	.742	.848	.954
3X4=	1	1	1	1	1	1	1	1	1	1	(1)	1	1	.068	.137	.205	.273	.341	.409	.477
3X10=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	(1)	.083
8X4=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4X12=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3X9=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8X7=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11x5=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6X8=	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
...																				

Figure 4   Priority Scores by Trial for Sample Sequence in Figure 3.   Columns indicate trials; rows show a partial list of problems in the database.   Circled priority scores indicate the problem chosen by the algorithm for that trial. Parameter values: a = .1; b=2; W=12; D=2; k=1; r=2
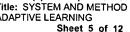
TRIAL	PROBLEM	RESPONSE	RESPONSE ACCURACY	TIME (sec)	COMMENT
1	camino	"road"	CORRECT	3.5	Fast, correct response.
2	Martes	"March"	WRONG	--	Incorrect response.
3	dos	"two"	CORRECT	18.4	Correct but slow.
4	verde	"Don't know"	WRONG	--	
5	anaranjado	"angel"	WRONG	--	
6	Martes	"Tuesday"	CORRECT	15.0	Recurrence of problem missed o
7	Abril	"April"	CORRECT	10.4	
8	facil	"easy"	CORRECT	2.6	
9	verde	"green"	CORRECT	9.7	Recurrence of problem missed o
10	anaranjado	"apple"	WRONG	--	Recurrence of problem missed o
11	Viernes	"Friday"	CORRECT	4.8	
12	azul	"blue"	WRONG	--	
13	dos	"two"	CORRECT	2.4	Recurrence of problem answere
14	Noviembre	"November"	CORRECT	8.6	
15	anaranjado	"orange"	CORRECT	11.3	Recurrence of problem missed o
16	cero	"zero"	CORRECT	2.7	
17	camino	"road"	CORRECT	6.2	Recurrence of problem answere
18	Martes	"Tuesday"	CORRECT	5.1	Recurrence of problem answere
19	hija	"daughter"	CORRECT	3.2	
20	empujar	"orange"	WRONG	--	

Figure 5. Sample Sequence of Trials Using the Sequencing Algorithm with Parameters Set to Favor Introduction of Relevant parameter values: a = .1, b = 1.5, D = 2, r=2, W = 6, K = 1.2

TRIAL

PROBLEM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
camino	(1.2)	-.09	0	.09	.18	.27	.37	.46	.55	.64	.73	.82	.92	1.01	1.1	1.19	(1.25)	-.09	0	.09
Martes	1.2	(1.2)	-0.6	0	0.6	(1.2)	-0.14	0	.14	.28	.42	.56	.70	.84	.98	1.11	1.25	(1.39)	-.08	0
dos	1.2	1.2	(1.2)	-0.16	0	.16	.32	.49	.65	.81	.97	1.13	(1.3)	-.12	0	.12	.25	.37	.49	.61
verde	1.2	1.2	1.2	(1.2)	-0.6	0	.6	1.2	(1.8)	-0.12	0	-0.12	.23	.345	.46	.58	.69	.81	.92	1.04
anaranjado	1.2	1.2	1.2	1.2	(1.2)	-0.6	0	.6	1.2	(1.8)	-0.6	0	.6	1.2	(1.8)	-.12	0	.12	.25	.37
Abril	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-.08	0	.08	.17	.25	.34	.42	.51	.59	.68	.76	.85	.93
facil	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-.09	0	.09	.18	.27	.37	.46	.55	.64	.73	.82	.92
Viernes	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-0.16	0	.16	.33	.49	.66	.82	.99	1.15
azul	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-.07	0	.07	.13	.20	.26	.33	.40
Noviembre	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-0.11	0	.11	.22	.33	.44
cero	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-.09	0	.09	.19
hija	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)	-0.6
empujar	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	(1.2)
amarillo	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Lunes	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
rosado	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2

FIGURE 6. Priority Scores by Trial for Sample Sequence in Figure 5. Columns indicate trials; rows show a partial list of problems in the database. Circled priority scores indicate the problem chosen by the algorithm for that trial. Parameter values: a = .1; b=1.5; W=6; D=2; k=1.2; r=2.

FIGURE 7. PERCEPTUAL LEARNING MODULE

FIGURE 8. PERCEPTUAL LEARNING SYSTEM: *STRUCTURE DISCOVERY* VARIANT

PROBLEM PRESENTATION FORMATS - DETAIL

PATTERN CLASSIFICATION

TRIAL PRESENTATION

206A

<QUERY>

[General Form: IS INSTANCE I AN EXAMPLE OF CONCEPT J?] — 70

<DISPLAY POSITIVE INSTANCE> OR <DISPLAY NEGATIVE INSTANCE> — 72

LEARNER RESPONSE

207 — RESPONSE OPTIONS

YES   NO

208 — CATEGORIZATION RESPONSE

PATTERN COMPARISON

TRIAL PRESENTATION

<QUERY>

[General Form: WHICH OF THESE DISPLAYS ARE EXAMPLES OF CONCEPT J?] — 70 — 206B

<DISPLAY INSTANCE I_1> <DISPLAY INSTANCE I_2> ··· <DISPLAY INSTANCE I_n> — 72

LEARNER RESPONSE

RESPONSE OPTIONS — 207

I_1 I_2 ··· I_n

CATEGORIZATION RESPONSE — 208

FIGURE 9. PERCEPTUAL LEARNING SYSTEM: *STRUCTURE MAPPING* VARIANT

PROBLEM PRESENTATION FORMATS - DETAIL

PATTERN CLASSIFICATION

TRIAL PRESENTATION

<DISPLAY INSTANCE i IN REPRESENTATIONAL FORMAT I>   69

<QUERY>
[General Form:
DOES INSTANCE i IN REPRESENTATIONAL FORMAT I REPRESENT THE SAME CONTENT OR STRUCTURE AS OF CONCEPT j?]   70

206C

<DISPLAY POSITIVE INSTANCE IN REPRESENTATIONAL FORMAT II>   OR   <DISPLAY NEGATIVE INSTANCE IN REPRESENTATIONAL FORMAT II>   71

LEARNER RESPONSE

RESPONSE OPTIONS
(YES) (NO)   207

CATEGORIZATION RESPONSE   208

PATTERN COMPARISON

TRIAL PRESENTATION

<DISPLAY TARGET INSTANCE i IN REPRESENTATIONAL FORMAT I>   69

<QUERY>
[General Form: WHICH DISPLAY(S) REPRESENT THE SAME CONCEPT OR STRUCTURE AS TARGET INSTANCE I?]   70

206D

<DISPLAY INSTANCE i_1>   <DISPLAY INSTANCE i_2> ... <DISPLAY INSTANCE i_n>   71

LEARNER RESPONSE

RESPONSE OPTIONS
(i_1) (i_2) ... (i_n) 207

CATEGORIZATION RESPONSE   208

FIGURE 10

HINTING ALGORITHM: OVERVIEW

Attorney: Art Hasan
Docket No.: 42055/SAH/K415
Inventor(s): Philip J. Kellman, Ph.D.
Title: SYSTEM AND METHOD FOR
ADAPTIVE LEARNING
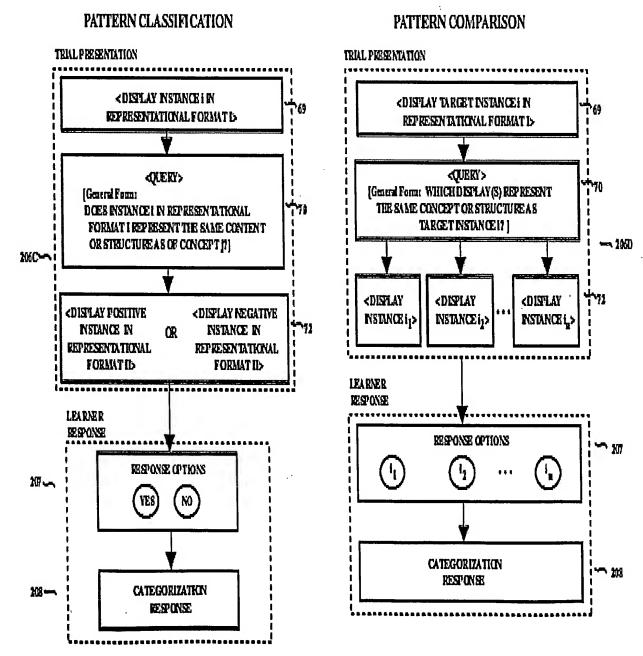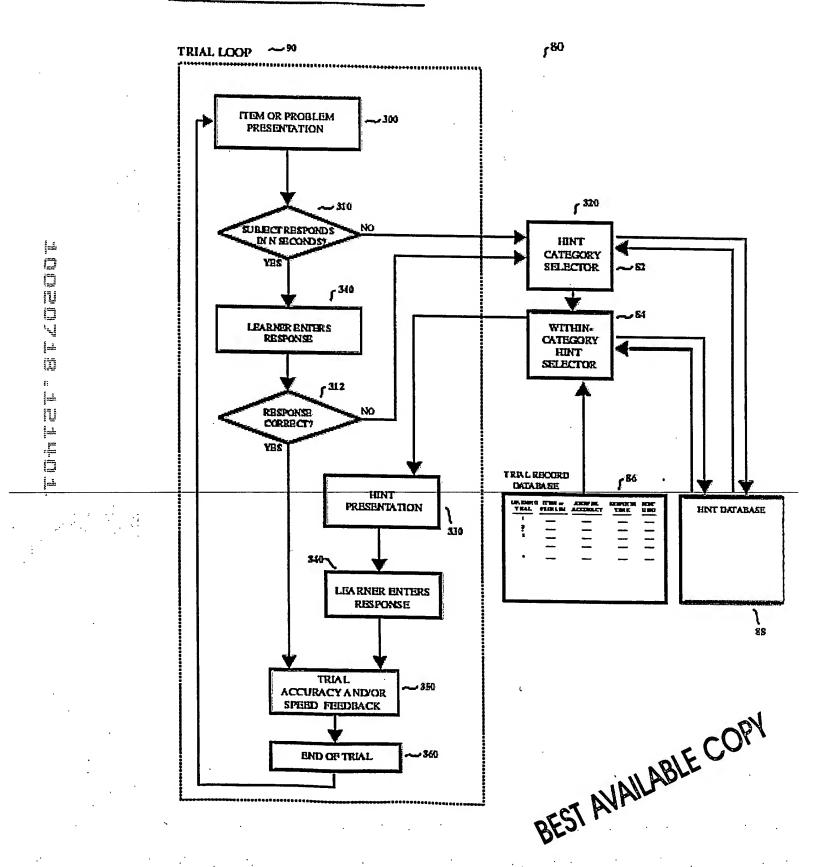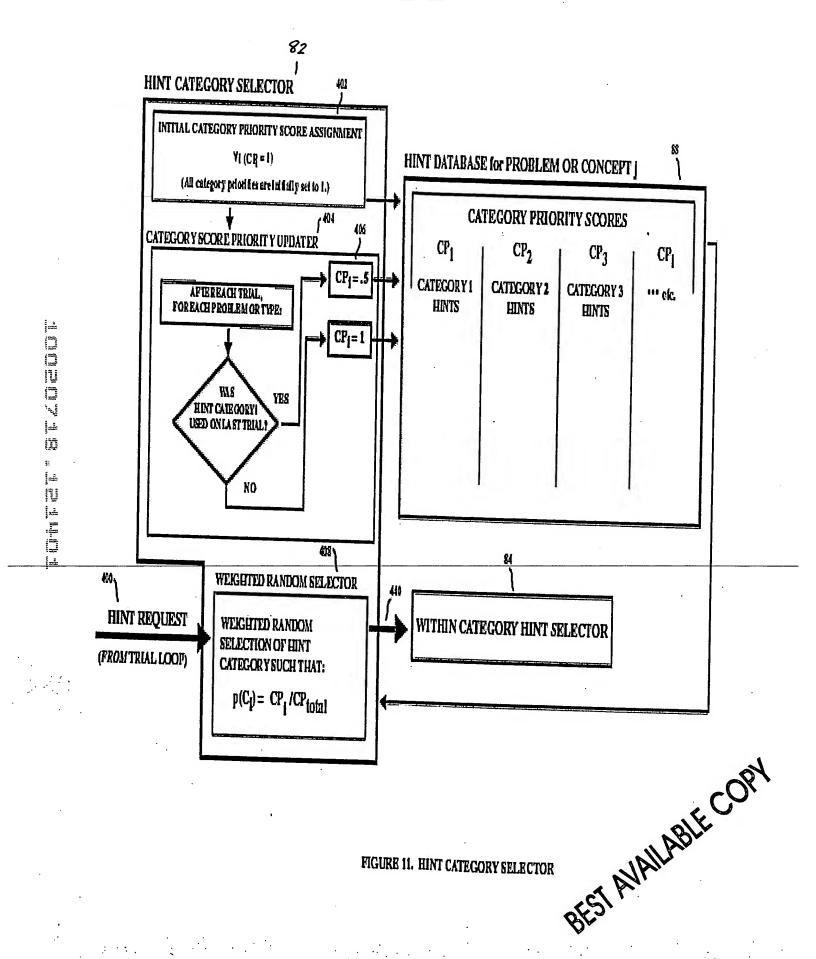Sheet 11 of 12

FIGURE 11. HINT CATEGORY SELECTOR

Attorney: Art Hasan
Docket No.: 42055/SAH/K415
Inventor(s): Philip J. Kellman, Ph.D.
Title: SYSTEM AND METHOD FOR
ADAPTIVE LEARNING
Sheet 12 of 12

WITHIN CATEGORY HINT SELECTOR   84

HINT PRIORITY SCORE COMPUTER

INITIAL PRIORITY ASSIGNMENT   450

$Y_i (HP_i = 1)$

(All hints given initial priority score of 1.)

↓

HINT PRIORITY SCORE COMPUTER   460

AFTER EACH TRIAL,
FOR EACH PROBLEM OR TYPE i

↓

FOR EACH HINT CATEGORY

↓

WAS A HINT FROM THIS CATEGORY USED ON THIS TRIAL? — NO → EXIT (No score changes)

↓ YES

WAS HINT i USED ON LAST TRIAL THAT USED THE HINT CATEGORY? — YES → $HP_i = 0$ 464

↓ NO   468

$HP_i = 1 + ((1 - \alpha_i) / RT_i)$

TRIAL RECORD DATABASE   86

(supplies performance data α_i, RT_i)

440
HINT REQUEST
(FROM HINT CATEGORY SELECTOR)

SPECIFIC HINT SELECTOR   470

HINT DATABASE for PROBLEM OR CONCEPT j   83

CATEGORY 1 HINTS		CATEGORY 2 HINTS		... etc.
HINT	PRIORITY SCORE	HINT	PRIORITY SCORE	
HINT 1	HP_1	HINT 1	HP_1	
HINT 2	HP_2	HINT 2	HP_2	
HINT 3	HP_3	HINT 3	HP_3	
↓	↓	↓	↓	
HINT i	HP_i	HINT i	HP_i	

480
HINT OUTPUT
(TO DISPLAY)

FIGURE 12. WITHIN-CATEGORY HINT SELECTOR